Interrelated Orogenic Building and Subsequent Extension at the Contact Between the Dinarides and the Pannonian Basin

Stojadinovic, U.

2014

1 | Introduction

1.1 Introduction

The interplay between shortening taking place at convergent boundaries and the roll-back process associated with mature subduction zones often results in the formation of extensional back-arc basins (e.g. *Dewey, 1981*; *Doglioni et al., 2007*; *van der Meer et al., 2010; van Hunen and Allen, 2011*). The rifting process responsible for the formation of extensional basins overlying continental lithosphere ultimately generates its break-up and the formation of oceanic crust, as widely observed in back arcs associated with the roll-back of mature subducting slabs, such as in the Caribbean or the Black Sea (*Okay et al., 1994*; *Meschede and Frisch, 1998*). During the onset of back-arc extension, the collapse of orogenic wedge is often accompanied by the formation of large scale extensional detachments along which significant amount of exhumation is recorded by uplifting footwalls, exposing core-complexes at the surface. These detachments and associated core-complexes are often superposed over a nappe stack that is inherited from previous orogenic shortening (e.g. *Lister, 1984*; *Lister and Davies, 1989*; *Lister et al., 2001*; *Brun and Faccenna, 2008*). The overprinting of collisional processes by back-arc extension driven by the slab retreat is typical case for Mediterranean orogens such as

Hellenides, Dinarides, Apennines or Carpathians (*Spakman, 1990*; *Faccenna et al., 2004, 2005*; *van Hinsbergen et al., 2005*; *Matenco et al., 2007*). Furthermore, changes in subduction polarities across European orogens resulted in zones of interaction between back-arc processes that are driven by different slabs (e.g., Alpine versus Dinaridic polarity, *Bernoulli et al., 1990*; *Kissling et al., 2006*; *Schmid et al., 2008; Matenco and Radivojević, 2012*).

Situated near the suture between the Dinarides (i.e. Adria-derived units) and the Carpatho−Balkanides (i.e. European-derived Dacia and Tisza units), along the southern flank of the Pannonian Basin, the NE margin of the Dinarides represents a key area for studying the evolution of the Europe–Adria collision zone in terms of orogenic and back-arc interactions. Following the progressive closure of the intermediate Neotethys/Vardar ocean, the European and Adria margins were juxtaposed during the late Cretaceous formation of the Sava suture zone (e.g., *Schmid et al., 2008; Ustaszewski et al., 2009*). This orogenic evolution has been subsequently overprinted by the Miocene extension of the Pannonian Basin. Defined as a continental back-arc basin driven by the retreat of a slab situated at the exterior of the Carpathians, the Pannonian Basin extension was accompanied by E-ward translations and opposite sense rotations of the two main intra-Carpathians units, ALCAPA and Tisza−Dacia (*Horváth et al., 2006*; *Royden, 1988*). The relationship between this Miocene extension and its connection S- and SW-wards with the collapse of the Dinarides and Hellenides (*Brun and Sokoutis, 2010; Schefer, 2010*) in the context of the retreat of a slab whose continental remnants are presently observed in the external part of the Dinarides (*Bennett et al., 2008*) is still unknown and needs to be investigated. The rapid E-ward drift and rotations of Tisza–Dacia units driven by the slab-roll back at the exterior of the Carpathians ceased by the end of Miocene times (~9 Ma, *Matenco et al., 2010*). The main driving mechanism in the area of the Pannonian Basin changed from the back-arc extension to the Adriatic indentation (*Horvath et al., 1995*). This resulted in formation of numerous Pliocene−Quaternary contractional to transcurrent structures that are distributed all across the basin (*Pinter et al., 2005; Jarosinski et al., 2011*). However, the effects of this inversion into the Pannonian basin margin adjacent to the Dinarides appear to be more reduced and started earlier, during the latest Miocene times, than elsewhere in the Pannonian basin (*Matenco and Radivojević, 2012*).

In order to define the relationships between orogenic building and subsequent extension detailed low temperature thermochronological investigations were conducted in three key orogenic areas, i.e. Fruška Gora, Cer, and Bukulja Mountains of Serbia, situated along the NE margin of the Dinarides. For this purpose an approach of multi-dating techniques is needed, combining zircon fission-track (ZFT), apatite fission-track (AFT) and apatite U–Th/He dating (AHe) of magmatic, metamorphic, and sedimentary rocks from these three areas. The main aim of this study was to obtain precise quantitative determinations of timing, rates and amounts of vertical movements associated with main tectonic processes acting during the dynamic evolution of the NE Dinarides.

When correlated with novel kinematic and structural investigations, as well as with the results of magmatic, metamorphic and paleontological dating, the results of this study yielded significant new inferences for the regional evolution of the Dinarides, Carpathians, and the Pannonian Basin.

1.2 **Thesis outline**

Following this introduction, chapter 2 gives detailed information on the geological evolution of the Fruška Gora, Cer, and Bukulja Mountains, and the surrounding areas belonging to the NE Dinarides. The introductory segment of the chapter provides overview of the main tectonic units of the Dinaridic orogen, accompanied by the general geological evolution of the three research areas. Types and correlation of the main metamorphic and stratigraphic units with diagnostic results of paleontological dating are provided, as well as the results of recent field kinematic and structural analyses. Furthermore, the newly obtained U-Pb zircon ages, which set the constraints on the timing of the onset of emplacement of the Cer and Bukulja intrusions, are presented.

In chapter 3, the main principles of low-temperature thermochronology and related analytical procedures used to obtain the data for the present study are explained. In addition, a brief technical description of the HELIOS noble gas line, after its major upgrade, is presented.

Chapter 4 provides the results of the multi ZFT, AFT, and AHe thermochronology dating applied for obtaining timing and rates of exhumation in the three key orogenic areas of the NE Dinarides. Time-temperature modeling of apatite fission track data (age, fission track lengths and etch pit diameters) together with geological evidence was applied using the HeFty program. The obtained detailed exhumation histories were subsequently correlated with existing kinematic studies in the same areas, which enabled the differentiation of associated genetic processes. Furthermore, by relating the regional exhumation and subsidence patterns from the Carpathians and Pannonian Basin with those of the Dinarides, the overall mechanism driving the extensional exhumation in this sector of the orogen is proposed.

Chapter 5 yields the results of combined ZFT and AFT detrital thermochronology study of several key sedimentary sequences, ranging from the Cretaceous to the Upper Miocene, in the areas surrounding the Fruška Gora, Cer, and Bukulja Mountains of the NE Dinarides. These sediments were deposited in the zones that presumably underwent significant tectonic activity during the phases of Europe–Adria shortening, collision and subsequent rifting related to the Pannonian extension. The lag-time concept is used to obtain estimates of exhumation rates and when possible constraints are deduced of the processes triggering exhumation in the hinterland. Single grain multi-dating of conglomerates reveals crucial information on timing of deposition of the sediments as well as and on exhumation of the hinterland. The obtained results allow for the reconstruction of thermal histories and exhumation of potential source areas, as well as, locally, a more precise determination of sediment ages and affiliation. Consequently, significant inferences about the long-term dynamic evolution of the NE Dinarides have been made.

Chapter 6 provides an overview of the low temperature thermochronology data presented in chapters 4 and 5, and their integration on the regional scale. The regional scale comparison of the observed time-temperature patterns allowed for the reconstruction of the structure of the Dinarides–Carpathians suture zone and the exhumation history related to the Pannonian extension. These findings, combined with the results of structural investigations, petrological, and paleontological dating presented in chapter 2, were subsequently integrated into the general evolution of the Dinarides, Carpathians, and the Pannonian Basin.